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## EFFECTS OF THE DECEMBER 1983 AND JANUARY 1985 FREEZING AIR TEMPERATURES ON SELECT AQUATIC POIKILOTHERMS AND PLANT SPECIES OF MERRITT ISLAND, FLORIDA

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**ABSTRACT:** Freezing air temperatures during the periods 25-26 December 1983 and 20-23 January 1985 resulted in hypothermal stress and mortality of several aquatic poikilotherms in the upper Indian River lagoon system, Brevard County, Florida. Twenty-three species of fish representing 15 families were found stressed or dead in the 1983 freeze and nine species representing 8 families were observed in the 1985 freeze. One hundred and fifty-two sea turtles were rescued from lagoonal waters in January 1985 of which 145 were *Chelonia mydas* (green turtle), and 7 were adult *Caretta caretta* (Atlantic loggerhead). Numerous indigenous plant species of tropical and subtropical origin were extensively damaged. These included *Avicennia germinans*, *Laguncularia racemosa*, and *Rhizophora mangle*. Exotic plant species such as *Schinus terebinthifolius*, *Casuarina equisetifolia*, and *Melaleuca quinquenervia* were also damaged.

CONSECUTIVE yearly freezes severe enough to induce hypothermal stress and mortality among aquatic poikilotherms and to simultaneously cause substantial damage to numerous native and exotic plant species are unprecedented for the central east coast of peninsular Florida. On 25 December 1983, just past midnight, a massive cold front moved across the Merritt Island region of central coastal Brevard County. Early morning air temperatures on 26 December reached a low of  $-5.5^{\circ}\text{C}$ . Nearly 13 months later, between 20-23 January 1985, another intense freeze dropped air temperatures to a low of  $-6.6^{\circ}\text{C}$ . This paper addresses the impacts of these two freeze events on aquatic poikilotherms and plant species of Merritt Island, Florida.

Historically, most documentation of the effects of freezing and subfreezing temperatures on the biota of coastal peninsular Florida have concentrated on describing those effects on the aquatic fauna inhabiting the waters of the Gulf coast and the Florida Keys (Packard, 1871; Willcox, 1887; Finch, 1917; Storey and Gudger, 1936; Miller, 1940; Galloway, 1941; Rinckey and Saloman, 1964). The effects of freezing air temperatures on the aquatic fauna in Brevard County have been addressed (Bangs, 1895; Snelson and Bradley, 1978; Ehrhart, 1979). Finch (1917) stated that both coasts of Florida were affected by the cold wave of 2-4 February 1917, but mentioned general localities only for the west coast. Snelson and Bradley (1978), via personal communications with Brevard County residents, indicated that some fish were apparently affected by the cold winter of 1957-58 and that a substantial number were adversely affected in the 1962 cold wave as were sea turtles (pers. comm. Dr. L.M. Ehrhart, University of Central Florida).

Climate is known to control the distribution of organisms through average conditions or through periodic extremes such as freezes (Walter, 1979) and is probably most evident in transition zones between two different climatic regions. Briggs (1974) identified the fauna of the Indian River lagoon system, adjacent to Merritt Island, as characteristic of a transition zone between a subtemperate and a subtropical zone. Gilmore and co-workers (1978) identified stenothermic tropical Caribbean fishes as being sympatric with eurythermic temperate Carolinian species in some of Florida's estuaries including Tampa Bay, Sanibel Island and the Indian River lagoon. Stenothermic tropical and subtropical fishes were identified as the heaviest impacted species during the January 1977 freeze (Gilmore et al., 1978). Storey (1937) reviewed the ranges of fish that were adversely affected by freezing temperatures and identified species of tropical origin as "always hurt" in the proximity of Sanibel Island. Ehrhart (1979 and pers. comm.) identified the tropical green turtle as always impacted by hard freezes and prolonged periods of low air temperatures as documented for 1962, 1977, 1978, 1981, and 1985. Rinckey and Saloman (1964) suggested that the quick drop in water temperature in Tampa Bay had the greatest impact on tropical and subtropical fish species.

Greller (1980) mapped Merritt Island as a transition zone between a Temperate Broad-leaved Evergreen Forest and a Tropical Forest. Previous botanical studies of Merritt Island (Sweet, 1976; Poppleton et al., 1977; Sweet et al., 1979; Stout, 1980) have indicated the presence of species of tropical and subtropical distribution. The transitional characteristics of the terrestrial vegetation are illustrated by the distribution of tree species. Species reaching their northern limits of distribution on the coast between Merritt Island and St. Augustine include *Avicennia germinans* (black mangrove), *Laguncularia racemosa* (white mangrove), *Myrcianthes fragans* (nakedwood) and *Rhizophora mangle* (red mangrove) (Little, 1978). Certain introduced species including *Casuarina equisetifolia* (Australian pine), *Schinus terebinthifolius* (Brazilian pepper) and *Melaleuca quinquenervia* (melaleuca) originate from tropical and subtropical areas and are cold sensitive.

Few papers have discussed effects of freezing temperatures on flora while describing faunal responses for any given locality in coastal peninsular Florida. Storey and Gudger (1936) briefly described firsthand accounts of the destruction of vegetation, principally mangroves, on Sanibel Island with the assistance of reliable, long time residents. Miller (1940) briefly noted that obvious damage was done to native trees and introduced tropical plants from Miami to Key West. His discussion included key mahogany, royal palm, guava and red mangrove. Gilmore and co-workers (1978) mentioned the devastating effects of the freeze on red mangrove in the vicinity of Fort Pierce. Snelson and Bradley (1978) indicated that numerous subtropical components of the biota were affected but provided specific information only on fish. Stowers and LeVasseur (1983) noted damage to citrus, vegetable crops and mangroves but not fauna in west-central Florida from the January 1981 freeze. Caprio and Taylor (1984) noted freeze damage to certain forbs and graminoids in the Everglades from the January 1981 freeze but not to other components of the

biota. The 1894-95 freeze caused extensive mortality to mangroves throughout the Indian River area (Bangs, 1895; Davis, 1940).

**MATERIALS AND METHODS**—This work was conducted to document, in part, natural changes in Merritt Island ecosystems as part of the long term environmental monitoring and research program at the John F. Kennedy Space Center (KSC) (NASA, 1982). A reconnaissance survey on 27 December 1983 revealed that a moderate fish-kill occurred following the passage of an intense cold front. Surveys were made along the northern shorelines of NASA Causeway and Highway 528, both of which span the Banana River (Fig. 1). In addition, observations were made at Banana Creek and Kennedy Parkway, the Vehicle Assembly Building (VAB) Turning Basin, and a boat ramp located 2.8 km east of the VAB Turning Basin. All three sites have been dredged (3-9 m) and are havens and sometimes "death traps" (Tabb, 1966; Moore, 1976; Gilmore et al., 1978; Snelson and Bradley, 1978) for fish seeking refuge from abnormally cold water temperatures.

Representative specimens of each species impacted were collected, if possible, and were identified, measured and weighed. Water temperature was measured using a Yellow Springs Instrument (YSI) Model 33.

Surveys for the January 1985 freeze were conducted at the same locations as identified for 1983 with additional observations made along NASA Causeway and the Indian River, numerous deep drainage ditches, mosquito control impoundments and open water areas of the upper Banana River. Search and rescue missions for stressed lagoonal sea turtles were conducted by personnel of the United States Fish and Wildlife Service (USFWS) at the Merritt Island National Wildlife Refuge.

Water temperature, salinity and conductivity were measured using YSI Models 33 and 51B. Continuous (0.5 h interval) measurements of water temperatures were made at two locations using Hydrolab 2020 series data sondes. One site was an impounded lagoon, typically less than 0.5 m in depth. The second site was a small, somewhat protected lagoon located at the northern terminus of the Banana River. Both instruments were immersed approximately 15 cm beneath the water's surface. Water temperature data were reduced to depict a profile beginning on 20 January at midnight and continuing through 24 January 1985. Meteorological data were collected at a Permanent Air Monitoring Station (PAMS) located on KSC (Fig. 1).

Effects of the two freezes on terrestrial vegetation were evaluated during fieldwork for ongoing long term vegetation studies. No attempt was made to quantify vegetation damage from these events; however, various communities including dunes, strand, hammocks, scrub, cattail marshes, sand cordgrass marshes and mangrove swamps were examined after each freeze event.

**RESULTS—Meteorological and Hydrographic Data:** Yearly climatological data for KSC and Cape Canaveral have been collected since 1957. A monthly summary of data for December, January, and February is presented in Table 1 (Eastern Space and Missile Center, 1982).

A comparative statistical summary of ambient air temperatures for December 1983 and January 1985 respectively, are as follows: extreme maximum 32.2 and 26.6°C, mean maximum 23.7 and 19.1°C, overall mean 16.3 and 12.2°C, mean minimum 11.6 and 6.1°C and extreme minimum -5.5°C and -6.6°C. Daily air temperatures for December 1983 and December 1984 through January 1985 are presented (Fig. 2, 3, and 4).

TABLE 1. Historical air temperature data for John F. Kennedy Space Center and Cape Canaveral Air Force Station 1957-1982.<sup>a</sup>

Month	Temperatures, °C				
	Extreme Maximum	Mean Maximum	Overall Mean	Mean Minimum	Extreme Minimum
Dec.	29.4	21.1	16.7	11.7	-3.9
Jan.	28.9	20.7	15.6	11.1	-7.2
Feb.	30.6	20.6	15.6	10.6	-3.9

<sup>a</sup>Source: Eastern Space and Missile Center, 1982.

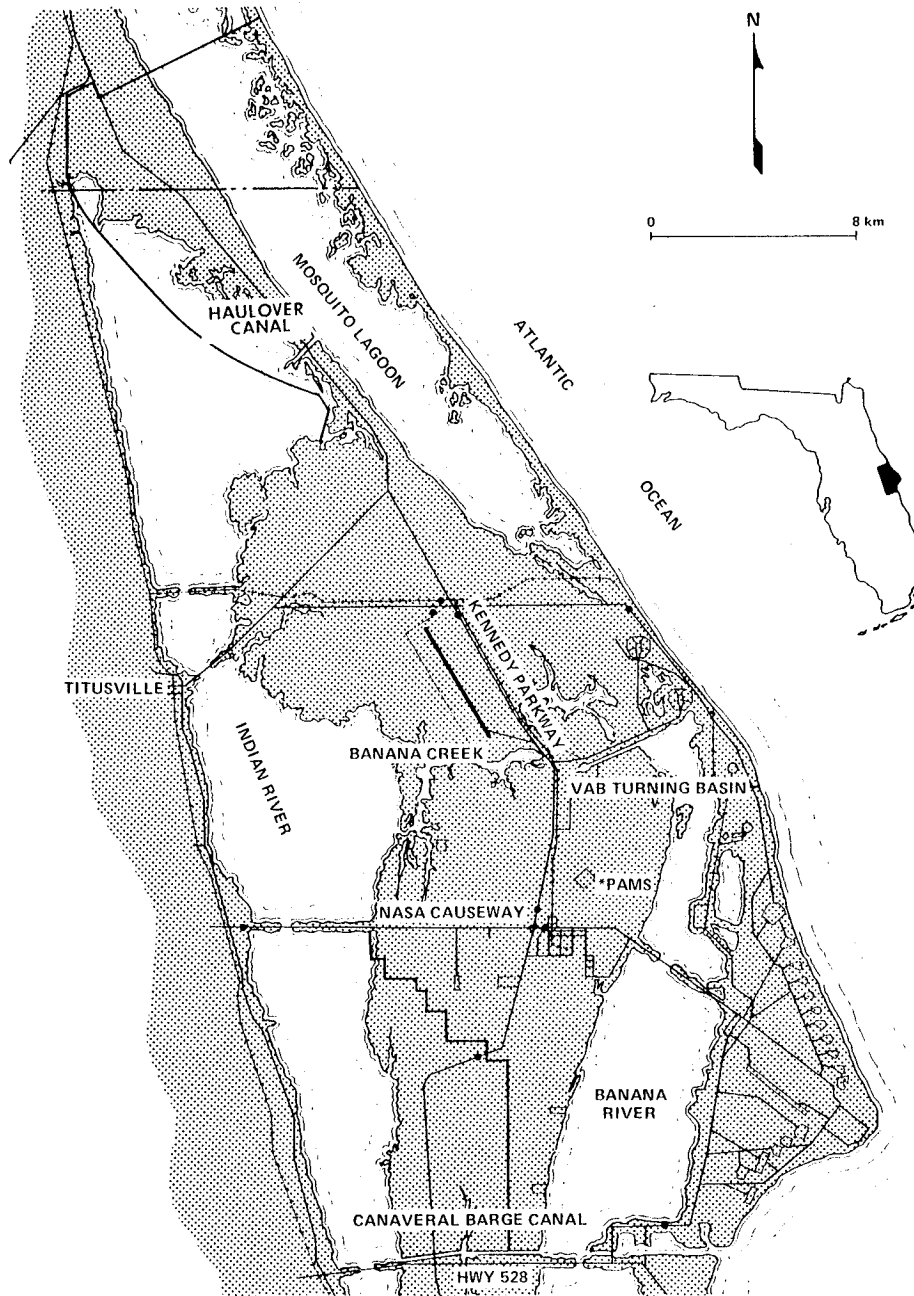


FIG. 1. Map of the John F. Kennedy Space Center and vicinity.

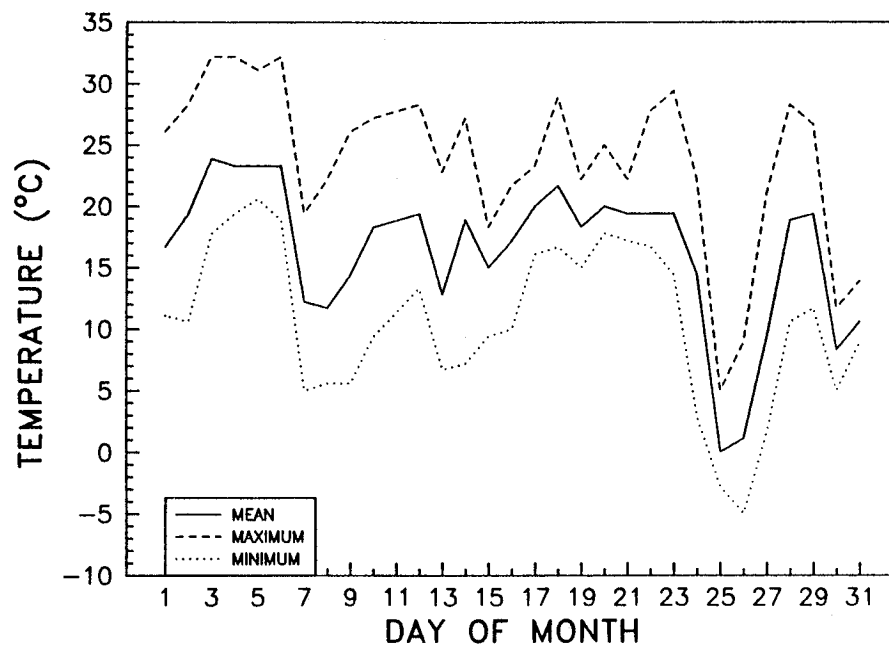


FIG. 2. Daily mean, maximum, and minimum air temperatures recorded at John F. Kennedy Space Center (KSC), Florida for December 1983.

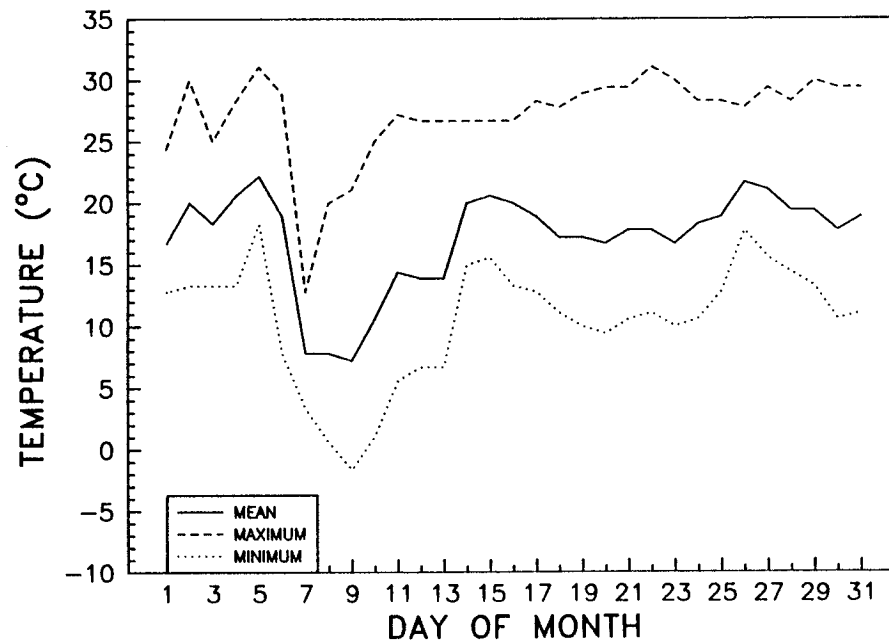


FIG. 3. Daily mean, maximum, and minimum air temperatures recorded at John F. Kennedy Space Center (KSC), Florida for December 1984.

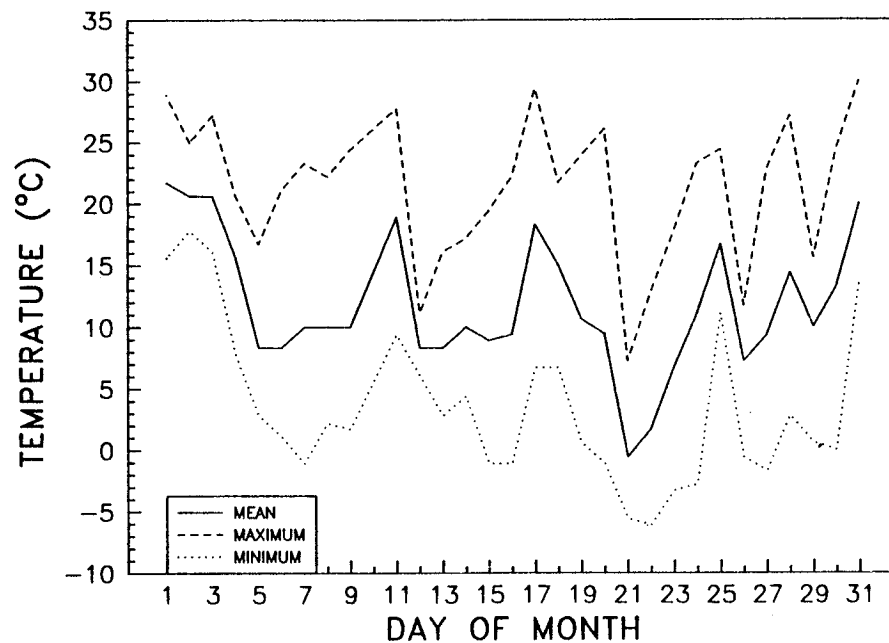


FIG. 4. Daily mean, maximum, and minimum air temperatures recorded at John F. Kennedy Space Center (KSC), Florida for January 1985.

Water temperatures were recorded at three general locations on 27 December 1983. These were the NASA Causeway Bridge and the Banana River, (9.0°C surface and 10.0°C at 5 m), the VAB Turning Basin, (13.0°C surface and 14.5°C at 4 m) and Banana Creek and Kennedy Parkway, (8.0-8.5°C surface). Surface temperatures recorded on 29 December at these same three locations were 13.0°C, 17.0°C and 18.0°C, respectively. Surface water temperatures in the VAB Turning Basin approximately one week prior to the freeze measured 20.0°C.

On 20 January 1985, water temperatures at the NASA Causeway bridge and the Banana River measured 15.0°C at the surface as well as at 5 m. Salinity measured 16.5 ppt. Surface water temperatures on 22 January 1985 along the north and south sides of NASA Causeway and Banana River measured 4.0°C and 2.8°C, respectively. Water depths at these two sites were 0.5 m and salinities measured 17.0 ppt. At the NASA Causeway bridge, water temperatures were 8.0°C surface and 9.0°C at 5 m. Water temperature recorded for the Indian River along the north side of NASA Causeway was 4.5°C and salinity measured 22 ppt. At Banana Creek surface and bottom (2 m) temperatures were 8.0 and 7.5°C, respectively.

Impounded water north of Launch Complex 39B reached a low of 2.8°C at 1000 h on 22 January (Fig. 5). Water temperature at this same location two days earlier was 15.0°C. The effects of rapid cooling were not nearly as dramatic at the open lagoonal station where a minimum temperature of 8.0°C was reached on 23 January. Three days earlier readings were near 14.5°C.

**FISHES:** A total of 23 species of fishes representing 15 families were observed and/or collected during field surveys following these two freezes. All have been previously documented from this region (Snelson, 1983). Listed below are those species affected by the December 1983 and January 1985 freezes. Notes on location, the freeze in which they were observed and length-weights are presented.

#### DASYATIDAE

*Dasyatis sayi* (bluntnose sting ray). What appeared to be either a large juvenile or adult specimen was observed motionless in approximately six centimeters of water adjacent to the northwest shore of Highway 528 Causeway and the Banana River. This specimen was not collected and therefore an accurate account of its condition could not be determined. Typically, large juveniles

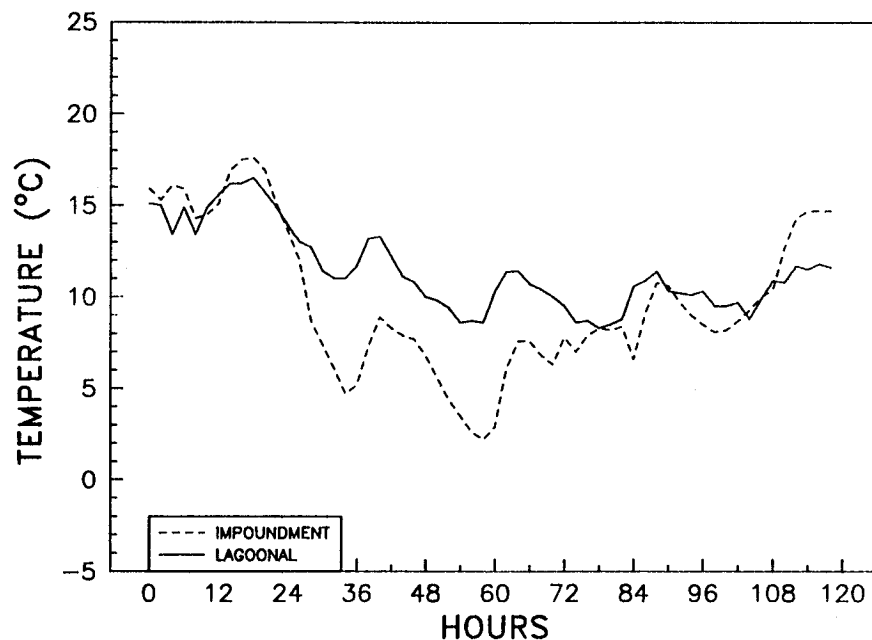


FIG. 5. Water temperature profile of a lagoonal station at the northern terminus of the Banana River and a shallow water mosquito impoundment for January 1985.

and adults are found in water deeper than 2.0 m (Snelson and Williams, 1981) and the occurrence of one in water just a few centimeters deep was unusual. Observed in the 1983 freeze, this specimen was the only cartilaginous species encountered during either freeze event.

#### ELOPIDAE

*Elops saurus* (ladyfish). One specimen (25.7 cm SL; 184 g) was collected along the north shore of NASA Causeway and the Banana River in December 1983. Several dead individuals of the same approximate size were observed in the general vicinity. Snelson and Bradley (1978) described this species as possessing tropical and subtropical affinities and recorded a few dead, ranging between 18-41 cm SL, in the January 1977 cold spell.

#### ALBULIDAE

*Albula vulpes* (bonefish). This species is of tropical-subtropical distribution and is rare in the upper Indian River lagoon system. One specimen (12.6 cm SL; 31 g) was collected in the 1983 freeze along the northwest shore of NASA Causeway and the Banana River. This represents only the third specimen documented from this area. This particular fish was observed dead on top of a floating mat of seagrass.

#### CLUPEIDAE

*Brevoortia* spp. (menhaden). One adult individual was observed along NASA Causeway and the Banana River in the 1983 freeze but was not retrievable.

#### ARIIDAE

*Arius felis* (sea catfish). In 1983, thousands of dead juveniles were observed floating in Banana Creek near Kennedy Parkway. No specimens were collected but the size class appeared extremely homogeneous (approximately 15 cm TL). Dead adults were observed along the northwest shore of Highway 528 Causeway and the Banana River in the proximity of the Canaveral Barge Canal several days following the freeze. Approximately 95% or more of the estimated 200,000 fish that floated to the surface were sea catfish (pers. comm. Mike Willard, Brevard County Biologist). In 1985, both moribund and dead specimens were collected at Banana Creek as well as the north shoreline of NASA Causeway and the Indian River. Specimens collected from the Indian River

measured between 26.7-32.5 cm TL and weighed from 113-276 g. Individuals collected from Banana Creek revealed a mixture of size classes measuring between 10.5-34.0 cm TL and weighing between 11-341 g. This species was observed in fewer numbers in the 1977 freeze (Snelson and Bradley, 1978).

*Bagre marinus* (gafftopsail catfish). One specimen (17.2 cm SL; 84 g) was collected along NASA Causeway and the Banana River in 1983 and another (20.5 cm TL; 62 g) along NASA Causeway and the Indian River in 1985. Contrastingly, Snelson and Bradley (1978) identified this species as the second most abundant fish killed in the VAB Turning Basin with the predominant size class measuring between 20-25 cm SL.

#### BELONIDAE

*Strongylura* spp. (needlefish). One dead specimen was observed in Banana Creek in 1983. It appeared to be about 25 cm TL. Snelson and Bradley (1978) described *Strongylura notata* as moderately impacted by the 1977 freeze.

#### CENTROPOMIDAE

*Centropomus undecimalis* (snook). Observed only in December 1983, this tropical-subtropical species was modestly impacted. One dead individual was observed along the northern shoreline of Highway 528 Causeway near the Canaveral Barge Canal. Approximately 20 specimens, measuring 76 cm TL or greater (pers. comm. Mike Willard, Brevard County Biologist), were observed dead in the Canaveral Barge Canal several days following the freeze.

#### CARANGIDAE

*Caranx* spp. (jack). A single specimen, estimated at 30 cm TL, was observed dead in Banana Creek at Kennedy Parkway in December 1983. In January 1985, dead specimens of *Caranx hippos* (jack crevalle) were commonly found, but only at Banana Creek. Individuals ranged from 30.3-41.3 cm TL and weighed between 337-675 g.

*Chloroscombrus chrysurus* (Atlantic bumper). One dead specimen (17 cm SL; 91 g) was collected in 1983 on the northern shore of NASA Causeway and the Banana River.

*Trachinotus falcatus* (permit). Moribund or dead specimens were common along the NASA Causeway and the Banana River in 1983. Moribund individuals exhibited a severe loss of equilibrium. Sixteen specimens were collected. Body lengths ranged from 20.4-37.5 cm SL and weights ranged between 319-1844 g. Snelson and Bradley (1978) found dead permit to be very abundant in the VAB Turning Basin.

#### GERREIDAE

*Eucinostomus harengulus* (spotfin mojarra). Eleven specimens (7.2-11.8 cm SL; 17-50 g) were collected in 1983 along the northeast shore of NASA Causeway and the Banana River in extremely shallow water. Some individuals were observed floating on seagrass mats while others were actually entangled within the mats.

*Eucinostomus gula* (silver jenny). One dead specimen (9.2 cm SL; 328 g) was collected in 1983 at the northeast shore of NASA Causeway and the Banana River.

*Diapterus olithostomus* (Irish pompano). Seventeen dead specimens (4.6-10.7 cm SL; 5-47 g) were collected along the north shore of NASA Causeway and the Banana River in 1983. These individuals were associated with mats of uprooted and broken seagrass.

*Diapterus plumieri* (striped mojarra). Several dead adult individuals were observed in very shallow water along the northwest shoreline of Highway 528 Causeway and the Banana River in 1983. Specimens were not collected; however, they appeared to be approximately 20 cm TL. A single specimen, measuring 30.5 cm TL and weighing 430 g, was collected from Banana Creek in January 1985.

#### SCIAENIDAE

*Cynoscion nebulosus* (spotted seatrout). One dead specimen (approximately 30 cm TL) was seen along the north shore of Highway 528 Causeway and the Banana River in 1983. In 1985, a dead individual (30.5 cm TL; 243 g) was collected along NASA Causeway and the Indian River.

*Bairdiella chrysoura* (silver perch). This species was observed in 1983 along Highway 528 Causeway and the Banana River. All specimens were dead and estimated to be about 10 cm TL.

#### EPHIPPIDAE

*Chaetodipterus faber* (spadefish). This species was observed in the Banana River during both freezes. Individuals were observed both dead or with impaired swimming. In 1983, individuals ranged from 11.1-26.8 cm SL and weighed from 93-1012 g. Those collected in 1985 ranged from 15.6-38.2 cm TL and weighed from 112-1275 g.

## MUGILIDAE

*Mugil cephalus* (striped mullet). A single dead specimen was observed along the north shore of Highway 528 Causeway and the Banana River in 1983. This specimen was not collected but was associated with numerous other species affected by the freeze.

## BALISTIDAE

*Aluterus schoepfi* (orange filefish). One dead individual was collected in 1983 along NASA Causeway and the Banana River approximately one kilometer east of the bridge. This specimen measured 36.1 cm SL and weighed 869 g.

*Monacanthus hispidus* (planehead filefish). This species was commonly observed along the north shore of NASA Causeway and the Banana River in the 1983 freeze. All individuals encountered were dead. Five specimens were collected that ranged from 16.2–24.8 cm SL and weighed between 149–542 g. In 1985, a single specimen (21.5 cm TL and 159 g) was collected dead at the same location as those in the 1983 freeze.

## TETRAODONTIDAE

*Sphoeroides nephelus* (southern puffer). Specimens collected in 1983 ranged from 16.8–17.7 cm SL and weighed between 162–217 g. In 1985, individuals collected measured between 20–27 cm TL and weighed between 140–370 g. This species was observed frequently along NASA Causeway and the Banana River. Individuals were encountered moribund or dead during both freezes.

## DIODONTIDAE

*Chilomycterus schoepfi* (striped burrfish). In 1983, five individuals collected along NASA Causeway and the Banana River ranged from 16–18.9 cm SL and weighed between 239–326 g. In 1985, individuals measured from 15.6–26.5 cm TL and weighed between 112–487 g.

**SEA TURTLES:** Stunned sea turtles were observed on 22 January 1985. A total of 145 *Chelonia mydas* (green turtle) were collected by members of the USFWS. Fourteen were “dead on arrival.” Eleven of the 145, described as large juveniles, were released into a nearby power plant thermal discharge. One hundred and twenty small juveniles were transported to Sea World, Inc. in Orlando, Florida where they were maintained until lagoonal water temperatures were above lethal limits. Seven adult *Caretta caretta* (Atlantic loggerhead) were also rescued and released in the power plant discharge (pers. comm. Dr. L.M. Ehrhart, University of Central Florida).

**VEGETATION:** Vegetation damage from the 25–26 December 1983 freeze was extensive. Along roadsides, dikes and groves, Brazilian pepper and Australian pine were damaged; extensive defoliation occurred and small to large branches on many trees were killed. Many individuals resprouted in spring and summer from the larger branches or trunks. Melaleuca was similarly damaged. These species suffered comparable damage during the January 1985 freeze.

Black, white and red mangroves fringing the Banana River, Banana Creek, Indian River and Mosquito Lagoon were adversely affected by the 1983 freeze. Leaves and small to large branches were killed. Some individuals resprouted while others were entirely destroyed by the freeze. Damage from the 1985 freeze was similar. Much of the regrowth which followed the 1983 freeze was killed as were some branches previously unaffected. In some places, branches near the water survived while those higher on the plant were killed indicating microclimatic amelioration of the freezing temperatures near the water.

In the coastal dune and coastal strand vegetation, *Coccoloba uvifera* (sea grape), *Chrysobalanus icaco* (coco-plum), *Scaevola plumieri* (beachberry), *Hymenocallis latifolia* (spider lily), *Rapanea punctata* (rapanea) and *Ipomoea pes-caprae* (railroad vine) were affected by the 1983 freeze. Sea grape, beachberry and coco-plum were generally killed back to the large stems or to ground level. Leaves of the spider lily and railroad vine were frozen. Rapanea suffered less severe but still obvious leaf damage. All species resprouted after the freeze. *Carissa grandiflora* (natal plum), an introduced African species present in some disturbed areas of coastal strand, was damaged. Damage from the 1985 freeze effected these same species in dune and strand communities. In addition, *Helianthus debilis* (beach sunflower) and *Heterotheca subaxillaris* (camphorweed) suffered some leaf damage from this freeze.

Hammock species affected by the 1983 freeze included *Nectandra coriacea* (lancewood), rapanea, *Ardisia escallonioides* (marlberry) and *Psychotria nervosa* and *P. sulzneri* (wild coffee). Typically, leaves and small stems of the sensitive species were killed but they later resprouted from the larger stems or from ground level. *Nephrolepis cordifolia* (Boston fern), common in the understory of hammocks, was partially defoliated by the freeze but resprouted from the rhizomes. Regrowth of these species was killed back by the 1985 freeze; however, new regrowth has occurred.

Other species affected by the 1983 and 1985 freezes included *Acrostichum danacifolium* (leather fern), common in brackish marshes on Merritt Island. Leaves of this fern were killed but it resprouted from the rhizomes. The 1985 freeze caused extensive die back of *Typha domingensis* and *T. latifolia* (cattail) which occupy numerous marshes on Merritt Island as well as drainage canals. The cattails have since resprouted from their rhizomes. Such damage was not noted after the 1983 freeze.

Damage to a number of herbaceous species was noted after the 1985 freeze; these included *Bidens alba* (beggar's tick), *Hydrocotyle* sp. (pennywort), *Phytolacca americana* (pokeweed), *Rivina humilis* (rouge plant) and *Vigna luteola* (cowpea). The introduced grass, *Arundo donax* (giant reed), was killed back by the freeze but has since resprouted. During mild winters these species continue growing. Freeze-damaged leaves were observed on the shrubs *Ica frutescens* (marsh elder), *Lantana camara* (shrub lantana) and *Mentzelia floridana* (poorman's patch).

Citrus groves on Merritt Island were also affected by the 1983 freeze. Those north of Haulover Canal appeared to be more damaged than those in the central or southern part of the island. The 1985 freeze produced a similar pattern of damage; greater defoliation of citrus was evident in the northern part of Merritt Island.

**DISCUSSION**—The ecological effects of the December 1983 and January 1985 freeze indicate the importance of such events in regulating species and community distributions associated with both aquatic and terrestrial systems. Hard freezes do not occur every year on Merritt Island. As a result, cold sensitive species generally have a period of recovery between freeze events. To our knowledge, two consecutive hard freezes like those observed the past two winters are unprecedented for east coastal peninsular Florida. Snelson and Bradley (1978), upon reviewing historical data from peninsular Florida, indicated that intervals between winters harsh enough to cause substantial mortality among fish populations ranged from 3 to 18 years and averaged 10 years between episodes. However, the upper Indian River lagoon has experienced three major freeze events (January 1977, December 1983, and January 1985) in the past eight years.

The 1983 freeze broke a 27-year record of  $-3.9^{\circ}\text{C}$  with a low of  $-5.5^{\circ}\text{C}$  on 26 December. The January 1985 freeze produced a low of  $-6.6^{\circ}\text{C}$ . The 1983 event appeared to have been more acute in rapidity of temperature decline. Temperatures declined from a daytime high of  $20.0^{\circ}\text{C}$  on 24 December at 1400 h to  $0.0^{\circ}\text{C}$  on the 25th at 0300 h. Storey and Gudger (1936) indicated that in the 1928 freeze, overnight temperatures dropped from  $21.0^{\circ}\text{C}$  to  $0.0^{\circ}\text{C}$  resulting in an extensive amount of damage. The severity of impact of a single cold spell on estuarine organisms or on terrestrial flora may vary with one or a combination of several factors including the minimum temperature obtained, the duration of this temperature and the rapidity of the temperature drop (Snelson and Bradley, 1978). The two successive freezes differed in some of these factors. Given this, it is difficult to determine which freeze was more severe.

Open lagoonal water temperatures were several degrees higher in 1983 than observed in 1977. Snelson and Bradley (1978) suggested that most open lagoonal organisms were subjected to water temperatures of  $4-6^{\circ}\text{C}$  for at least 48 h. The lowest lagoonal water temperature observed for December 1983 was  $9.0^{\circ}\text{C}$  and we believed that this was maintained for no longer than 36 h. Based on the recorded water temperature data as well as specific point readings

along the causeways, we feel that water temperature was maintained between 5-10°C for at least 48 h in 1985.

The "refuge death trap" (Tabb, 1966; Moore, 1976; Gilmore et al., 1978; Snelson and Bradley, 1978) was only evident in 1983 at the Canaveral Barge Canal and at Banana Creek and Kennedy Parkway. Apparently, thousands of young sea catfish became trapped in a dredged section near the bridge spanning Banana Creek. Evidence of the phenomenon at the Canaveral Barge Canal was not obvious until a few days after the freeze when water temperatures began to rise and dead fish appeared at the surface.

Of the 23 species of fish affected by the two freezes, all but five (*Dasyatis sayi*, *Albula vulpes*, *Chloroscombrus chrysurus*, *Chaetodipterus faber* and *Aluterus schoepfi*) were recorded in the 1977 freeze. Nine species, *Arius felis*, *Chilomycterus schoepfi*, *Caranx hippos*, *Sphoeroides nephelus*, *Chaetodipterus faber*, *Monacanthus hispidus*, *Bagre marinus*, *Cynoscion nebulosus* and *Diapterus plumieri*, were encountered during both freezes. Storey (1937) identified the first two of these nine species as "always hurt." We found *Arius felis*, *Chilomycterus schoepfi* and *Sphoeroides nephelus* to have the greatest number of individuals affected during each freeze.

Our observations concur with previous authors in describing fish affected by hypothermia. Species such as *Trachinotus falcatus* and *Monacanthus hispidus* were commonly seen at the surface swimming on their sides while *Chilomycterus schoepfi* and *Sphoeroides nephelus* were typically in an upright position floating near the surface with relatively little fin movement. Other species maintained an upright position while swimming but appeared very lethargic. We believe that many of these individuals could have survived had they not washed up on the northern shoreline of the causeways or became stranded in extremely shallow water. Some species such as *Eucinostomus gula*, *E. harengulus* and *Diapterus olisthostomos* became entangled or washed up onto floating mats of seagrass while in this condition and apparently suffocated as a result. Predation by birds was also observed to produce high mortality of stressed and stranded individuals.

The occurrence of stunned sea turtles in the Indian River lagoon system is not uncommon during extreme cold periods. In fact, cold-water stunning of lagoonal sea turtles may occur, to some degree, every winter (Ehrhart, 1979). Previous cold stunnings of sea turtles in the upper Indian River lagoon occurred in 1962, January 1977, January 1978, and January 1981 (Snelson and Bradley, 1978; Ehrhart 1979 and pers. comm.). In 1977, a massive rescue operation, orchestrated by Dr. L.M. Ehrhart of the University of Central Florida, resulted in the collection of 100 greens, 1 *Lepidochelys kempi* (Kemp's ridley) and 41 loggerheads. Water temperatures dropped from 11.5°C on 13 January 1977 to 4°C on 20 January. Between 15 and 21 January 1978, 5 greens were rescued as was 1 loggerhead. Water temperatures ranged between 8-10°C (Ehrhart, 1979). On 13 January 1981 water temperatures surveyed at Haulover Canal measured 3.5°C. By 20 January, a total of 163 turtles had been collected. Of the 88 greens captured, 76 survived. Seventy of the 74 loggerheads collected survived as did 1 Kemp's ridley (pers. comm. Bill

Leenhouts, USFWS and Dr. L.M. Ehrhart, University of Central Florida). Data strongly indicate that the tropical green turtle is more cold sensitive than the loggerhead (Ehrhart, 1979). Though the December 1983 freeze may be regarded as a hard freeze, its impact on lagoonal turtles was not apparent. We believe that this was due to two main reasons: 1) the freeze was not preceded by enough cold weather (Fig. 2) as observed in January 1985 (Fig. 4) and 2) that the freeze was immediately followed by a significant warming trend (Fig. 2). As a result, lagoonal sea turtles were not approaching a state of hypothermia when the freeze occurred in 1983 as they probably were in 1985.

The effects of periodic freezes on Merritt Island is clearly evident when viewing particular plant species such as red and black mangrove. These species reach large tree status in certain areas in southern Florida (Davis, 1940; Tomlinson, 1980) but are shrubs in the northern limits of their ranges due to periodic freezes.

The extent of damage to mangrove vegetation produced by the 1983 freeze suggested that several years would be required for the mangroves to return to their pre-freeze stature and distribution. The 1985 freeze killed much of the 1984 regrowth, increasing the time required for recovery to pre-1983 conditions. Mortality to mangroves on Merritt Island due to hard freezes is not unprecedented. Davis (1940) indicated that extensive mortality to mangroves on the island occurred from the 1894-95 freeze when air temperatures reached  $-5^{\circ}\text{C}$ . Mangroves occupy approximately 1530 ha (3780 ac) on KSC and are important in providing rookery sites for wading birds as well as good habitat for numerous fish species. The two successive freezes have substantially, though probably temporarily, affected these communities, reducing cover and biomass production until recovery occurs.

Most plant species adversely affected by the freeze have resprouted from undamaged parts such as large stems, roots and rhizomes. Even where some individuals were killed others in the population survived. Stout (1980) noted that the 1976-77 freeze damaged *Ardisia* and *Psychotria* in hammocks on Canaveral National Seashore in Volusia County and that these species recovered by sprouting. However, for cold-sensitive plant species at the margin of their range and present in small populations, a single freeze or the cumulative effect of a number of freezes may result in the elimination of such plant species. Poppleton (1981) reported that the 1977 freeze killed the population of *Tournefortia gnaphalodes* (sea lavender) which occurred on a dune north of Playalinda Beach on Canaveral National Seashore.

The December 1983 and January 1985 freezes were severe enough to cause substantial damage to local terrestrial vegetation, especially of tropical and subtropical distributions. Some of these plants will require years without severe freezes to regain their pre-freeze status. Fish, however, did not seem to be as severely affected as observed in January 1977. At that time, a greater number of individuals covering a much larger portion of the Indian River lagoonal system were affected. The impact to the lagoonal sea turtle population was as dramatic as in 1977 and 1981.

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